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(54) **DETERMINING MAXIMUM PACKET DURATION**

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H04L 1/18	(2006.01)
H04L 1/00	(2006.01)
H04W 84/12	(2009.01)

(52) **U.S. Cl.**

CPC ***H04W 74/0816*** (2013.01); ***H04L 1/0007*** (2013.01); ***H04L 1/1887*** (2013.01); *H04W 84/12* (2013.01)

(58) **Field of Classification Search**

CPC H04W 74/0816; H04W 74/0825; H04W 74/0841; H04W 74/085; H04W 74/0858; H04W 72/04; H04W 72/0406; H04W 72/08; H04W 72/082; H04W 72/085; H04W 72/12; H04W 72/1226; H04W 72/1231; H04W 72/1242

See application file for complete search history.

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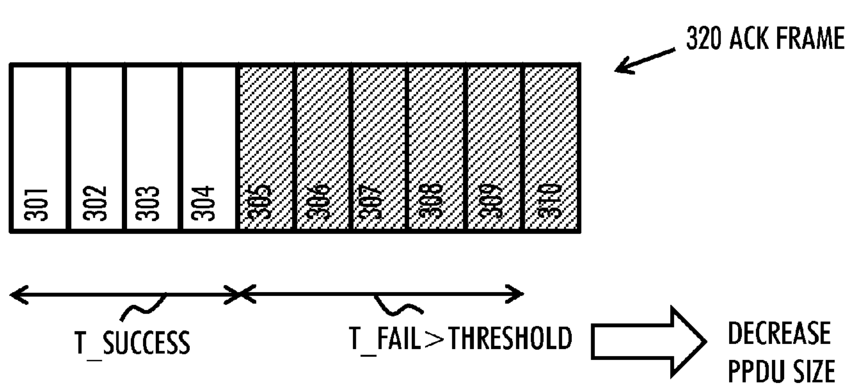
(57) **ABSTRACT**

There is provided a method comprising: determining, by a transmitter node, maximum packet duration for a data packet to be transmitted, wherein the data packet comprises a plurality of data units; causing a transmission of the data packet; causing a reception of an acknowledgement frame indicating a failed reception of multiple consecutive data units of the transmitted data packet; determining a transmission duration during which the failed multiple consecutive data units were transmitted; and determining whether or not to adjust the maximum packet duration for upcoming data packet transmissions on the basis of the determined transmission duration.

19 Claims, 5 Drawing Sheets



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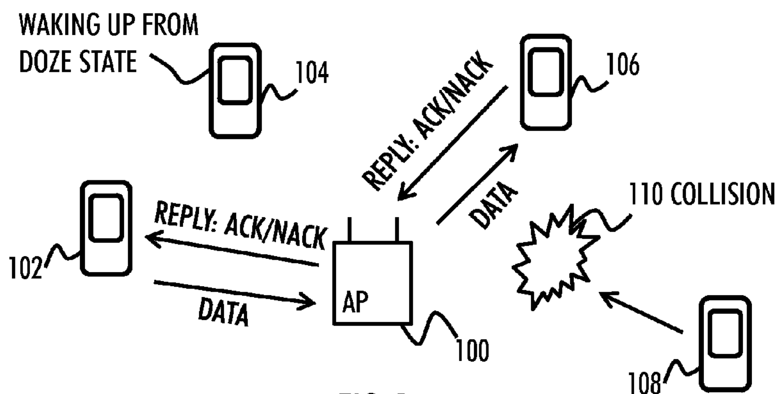
WAKING UP FROM
DOZE STATE
104
106
REPLY: ACK/NACK
DATA
110 COLLISION
REPLY: ACK/NACK
102
DATA
AP
100
108

FIG. 1

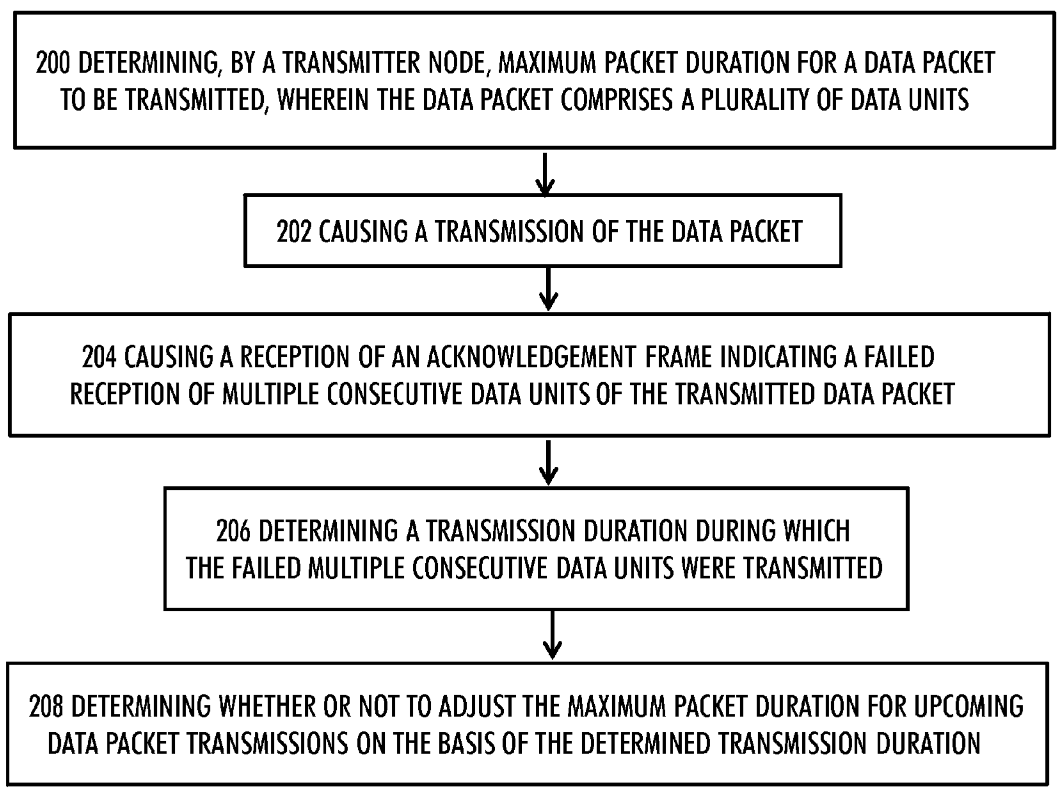
200 DETERMINING, BY A TRANSMITTER NODE, MAXIMUM PACKET DURATION FOR A DATA PACKET TO BE TRANSMITTED, WHEREIN THE DATA PACKET COMPRISES A PLURALITY OF DATA UNITS
202 CAUSING A TRANSMISSION OF THE DATA PACKET
204 CAUSING A RECEPTION OF AN ACKNOWLEDGEMENT FRAME INDICATING A FAILED RECEPTION OF MULTIPLE CONSECUTIVE DATA UNITS OF THE TRANSMITTED DATA PACKET
206 DETERMINING A TRANSMISSION DURATION DURING WHICH THE FAILED MULTIPLE CONSECUTIVE DATA UNITS WERE TRANSMITTED
208 DETERMINING WHETHER OR NOT TO ADJUST THE MAXIMUM PACKET DURATION FOR UPCOMING DATA PACKET TRANSMISSIONS ON THE BASIS OF THE DETERMINED TRANSMISSION DURATION

FIG. 2

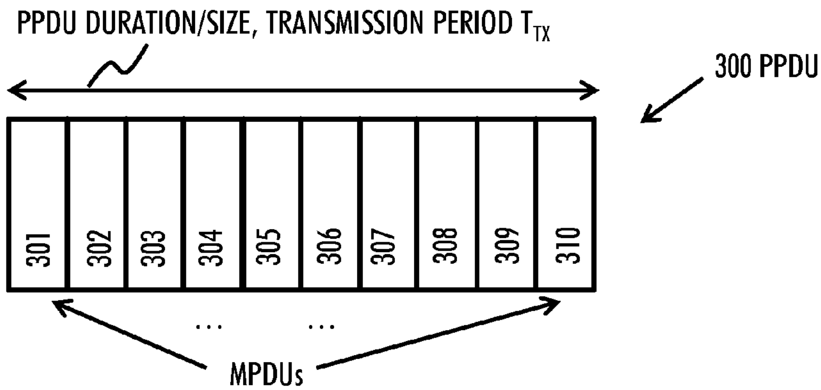
PPDU DURATION/SIZE, TRANSMISSION PERIOD T_{TX}
300 PPDU
301
302
303
304
305
306
307
308
309
310
...
...
MPDUs

FIG. 3A

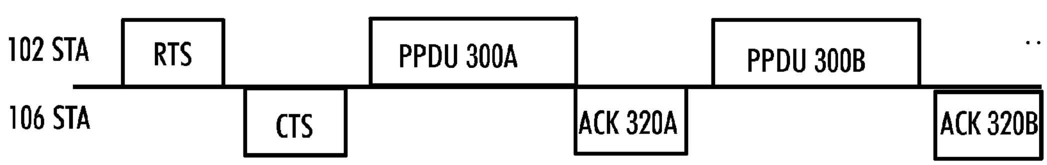
102 STA
106 STA
RTS
CTS
PPDU 300A
ACK 320A
PPDU 300B
ACK 320B
...

FIG. 3B

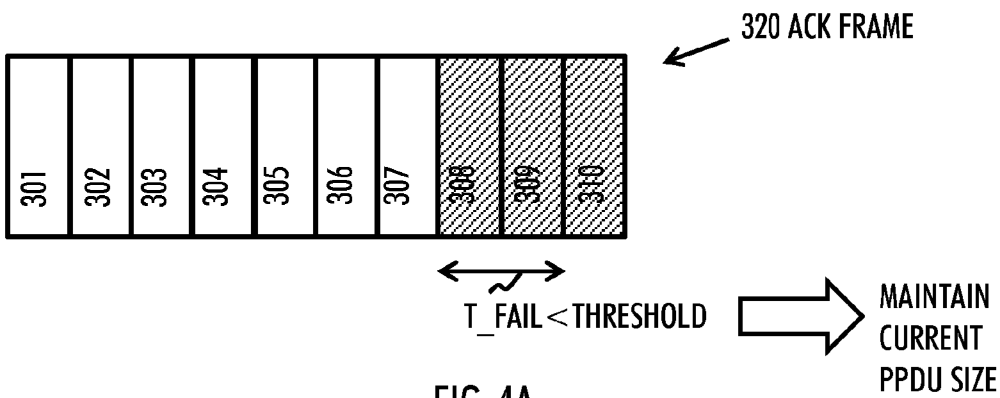

FIG. 4A

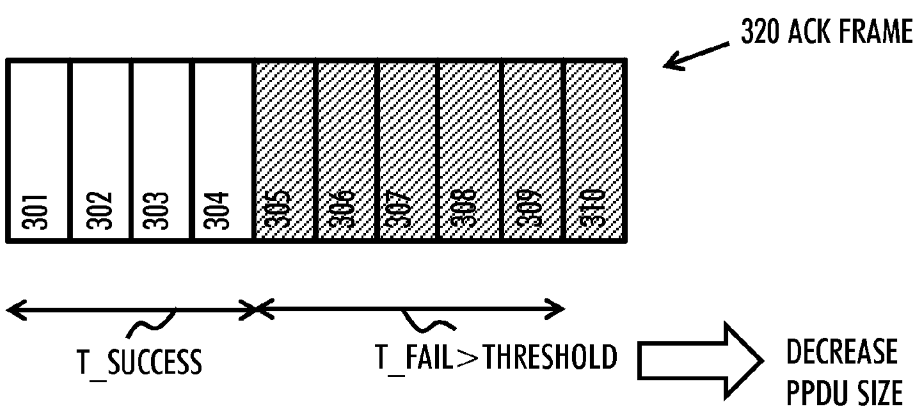

FIG. 4B

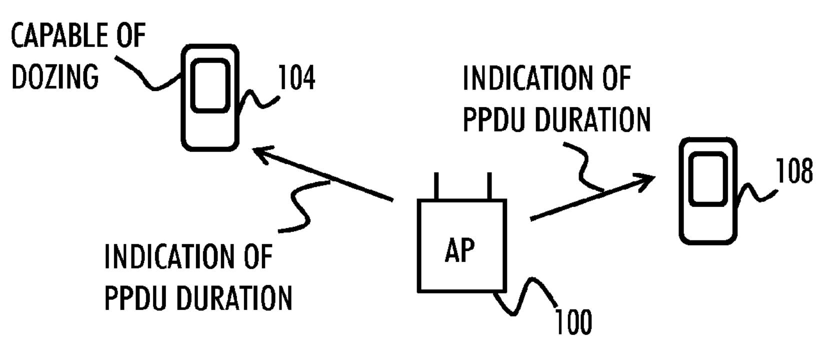

FIG. 5

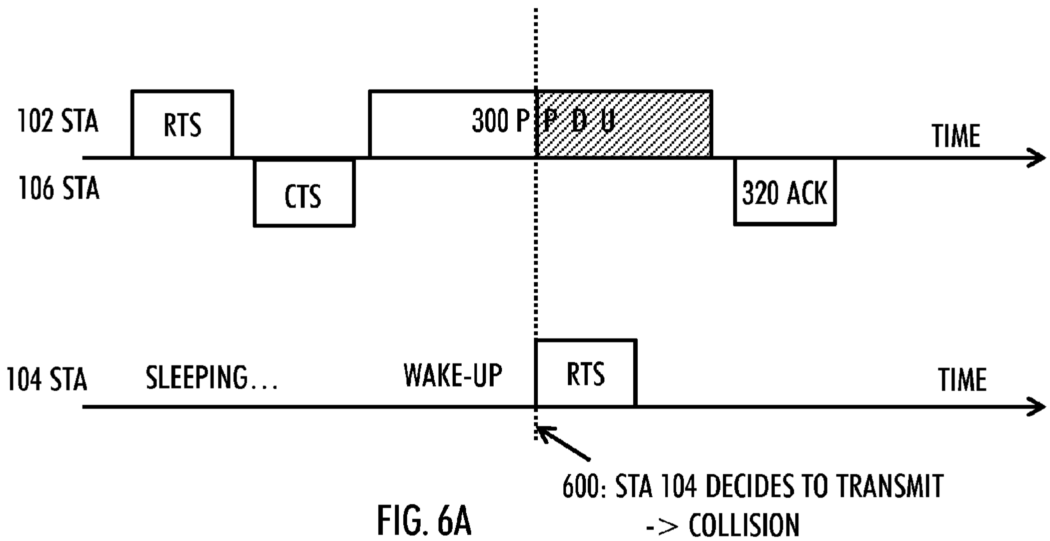
102 STA
RTS
300 P P D U
TIME
106 STA
CTS
320 ACK
104 STA
SLEEPING...
WAKE-UP
RTS
TIME
600: STA 104 DECIDES TO TRANSMIT
-> COLLISION

FIG. 6A

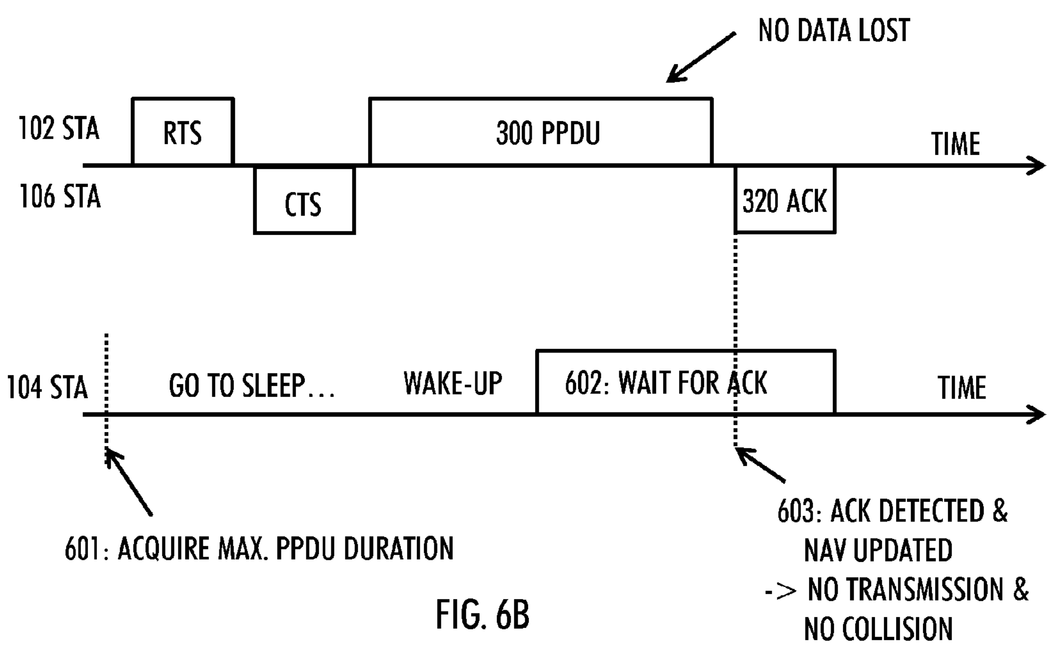
NO DATA LOST
102 STA
RTS
300 PPDU
TIME
106 STA
CTS
320 ACK
104 STA
GO TO SLEEP...
WAKE-UP
602: WAIT FOR ACK
TIME
601: ACQUIRE MAX. PPDU DURATION
603: ACK DETECTED &
NAV UPDATED
-> NO TRANSMISSION &
NO COLLISION

FIG. 6B

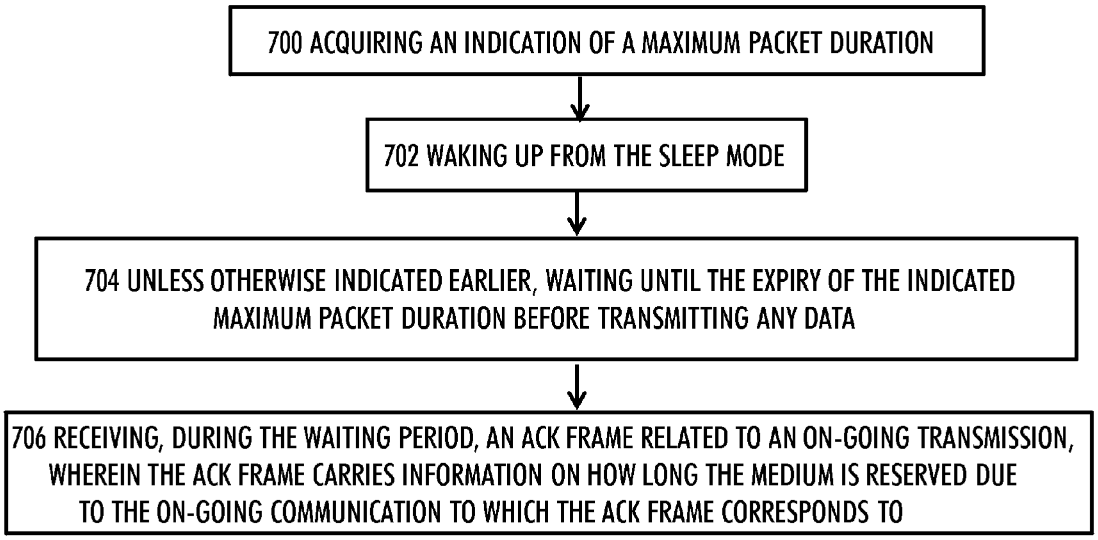
700 ACQUIRING AN INDICATION OF A MAXIMUM PACKET DURATION
702 WAKING UP FROM THE SLEEP MODE
704 UNLESS OTHERWISE INDICATED EARLIER, WAITING UNTIL THE EXPIRY OF THE INDICATED MAXIMUM PACKET DURATION BEFORE TRANSMITTING ANY DATA
706 RECEIVING, DURING THE WAITING PERIOD, AN ACK FRAME RELATED TO AN ON-GOING TRANSMISSION, WHEREIN THE ACK FRAME CARRIES INFORMATION ON HOW LONG THE MEDIUM IS RESERVED DUE TO THE ON-GOING COMMUNICATION TO WHICH THE ACK FRAME CORRESPONDS TO

FIG. 7

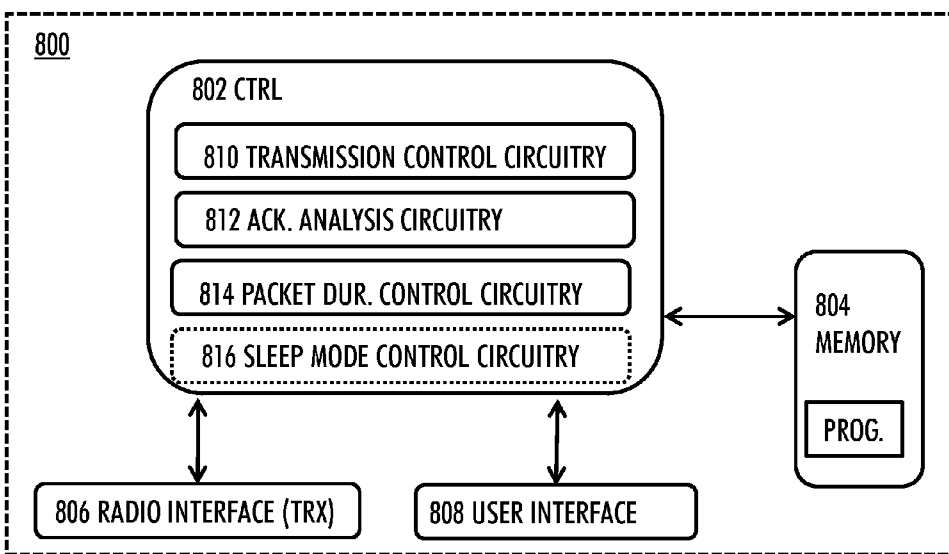
800
802 CTRL
810 TRANSMISSION CONTROL CIRCUITRY
812 ACK. ANALYSIS CIRCUITRY
814 PACKET DUR. CONTROL CIRCUITRY
816 SLEEP MODE CONTROL CIRCUITRY
804 MEMORY
PROG.
806 RADIO INTERFACE (TRX)
808 USER INTERFACE

FIG. 8

DETERMINING MAXIMUM PACKET DURATION

FIELD

The invention relates generally to improving communication efficiency in a wireless access network.

BACKGROUND

Typically wireless access networks perform better when the traffic load is small or moderate. Also when the density of the networks and terminals is small, the wireless access networks perform well. However, with a high number of users or a high traffic load, the communication efficiency may decrease. This may be, e.g., due to collisions of transmissions from different users.

BRIEF DESCRIPTION OF THE INVENTION

According to an aspect of the invention, there is provided a method as specified in claim **1**.

According to an aspect of the invention, there are provided apparatuses as specified in claims **10**.

According to an aspect of the invention, there is provided a computer program product as specified in claim **19**.

According to an aspect of the invention, there is provided a computer-readable distribution medium carrying the above-mentioned computer program product.

According to an aspect of the invention, there is provided an apparatus comprising means for performing any of the embodiments as described in the appended claims.

Embodiments of the invention are defined in the dependent claims

LIST OF THE DRAWINGS

In the following, the invention will be described in greater detail with reference to the embodiments and the accompanying drawings, in which

FIG. **1** presents a wireless access network, according to an embodiment;

FIG. **2** shows a method, according to an embodiment;

FIG. **3**A shows an example data packet, according to an embodiment;

FIG. **3**B shows an example negotiation during data transmission, according to an embodiment;

FIGS. **4**A and **4**B illustrate examples of acknowledgement frames, according to some embodiments;

FIG. **5** depicts a scenario where an access node controls transmits an indication of a maximum packet duration, according to an embodiment;

FIGS. **6**A and **6**B illustrate how a station waking up from a sleep mode may operate, according to some embodiments;

FIG. **7** shows a method, according to an embodiment; and

FIG. **8** illustrates an apparatus, according to an embodiment.

DESCRIPTION OF EMBODIMENTS

The following embodiments are exemplary. Although the specification may refer to "an", "one", or "some" embodiment(s) in several locations of the text, this does not necessarily mean that each reference is made to the same embodiment(s), or that a particular feature only applies to a single embodiment. Single features of different embodiments may also be combined to provide other embodiments.

The number of IEEE 802.11-enabled mobile devices is increasing. The IEEE 802.11 is a set of standards for implementing wireless local area network (WLAN), also known as the Wi-Fi. Such IEEE 802.11-enabled stations (STA), e.g. user terminals/equipment **102-108** in FIG. **1**, may associate and communicate with an access node/point (AP) **100**. The STAs **102-108** may comprise a mobile phone, a palm computer, a wrist computer, a laptop, a personal computer, or any device capable to access the wireless radio access network, such as the WLAN. The access node **100** may be a WLAN (IEEE 802.11) access point (e.g. Wi-Fi base stations), for example. Although in the following WLAN is used for the simplicity of the description, the embodiments may be applicable to other types of wireless access networks.

As the number of users (devices) is increasing, the requirements for communication efficiency in terms of reliability and throughput become more difficult to reach. For example, data transmission from the STA **108** may collide with the on-going data transmission between the STA **102** and the STA **106** (via the AP **100**), as shown with a reference numeral **110** in FIG. **1**. In order to avoid or at least to mitigate the problem of interference/collisions, the WLAN uses Enhanced Distributed Channel Access (EDCA) with physical carrier sensing, such as a Clear Channel Assessment (CCA), and virtual carrier sensing, such as a Network Allocation Vector (NAV). As such, when the physical and virtual carrier sensing indicate an idle channel, the STA **102-108** may reduce the value of the back-off. When the back-off is zero, the device (STA) **102-108** may obtain a transmission opportunity (TXOP) to transmit data. The physical and virtual carrier sensing try to avoid simultaneous transmissions that cause interference, e.g., collisions, to each other. The protection level thus depends on the carrier sensing mechanism applied, distance between the transmitters and the intended recipients, network topologies, antenna technology, amount of traffic, etc.

However, a power saving capable STA, such as the STA **104** may go to sleep (i.e. to a power save mode, also known as a doze mode/state). When a mobile device **104** is using the power save (e.g. is in the doze mode), the device **104** is not aware of the possibly on-going transmissions. In other words the STA **104** may rely only on the physical carrier sensing, such as the CCA. Likewise, if directive transmissions are applied, the NAV or CCA information may not be broadcasted to all devices **104**. As a consequence, when directed transmissions are being used, those devices that disturb the receiver of the directed transmission may not be aware of the on-going transmission(s) and, thus, cause interference to the transmission(s).

To improve the protection of the on-going transmissions (e.g. to avoid collisions), the devices **104** and **108** should be able to detect the on-going transmissions, such as the transmission between the STAs **102** and **106**. However, e.g. the power saving STAs **104** may not obtain the NAV information from the on-going data transmissions. This may be, e.g., due to the number of data streams, due to different modulation and coding schemes (MCS) being applied, as well as due to possible directive transmissions which may make the data frames of the on-going transmissions hard to detect by a STA **104**. It may also be noted that typically a link adaptation procedure tries to adapt the MCS to a specific interference level. However, in a free (unlicensed) frequency spectrum, such as the one used by the WLAN, the interference level may vary significantly in the channel. As a result, the NAV information updates may be undetected by some of the STAs **104**, **108** and, consequently, data transmission from the power saving STAs **104** and other STAs **108** that did not receive the NAV information may collide with the on-going transmissions.

Therefore, there is needed a solution to improve the communication efficiency and reliability by increasing the protection level of the on-going transmissions. This may take place by enabling a transmitter to define a maximum duration before a respond (MDBR) from a receiver/responder of an on-going transmission. In other words, the frequency/periodicity of responses (i.e. how often the responses are transmitted) from a receiver of a data transfer may be defined. It may be noted that the STAs **104**, **108** may more easily detect and decode the responses, such as an acknowledgement (ACK)-frame or a non-ACK (NACK)-frame from the receiver, than the data transmissions from the transmitter. The responses (e.g. the ACK/NACK) may also carry information related to the channel reservation, such as a NAV update. Thus, the response from the receiver may help in protecting the on-going transmission by indicating that the channel is reserved for the duration of the indicated NAV. Therefore, by applying an appropriate frequency for the responses carrying, e.g., the NAV updates, the STAs **104** and **108** may be more likely to detect the NAV update and to restrain from transmissions. In this way the frequent channel occupancy information updates may help in avoiding simultaneous transmissions that would cause interference and collisions of packets. Further, this may help to maintain a constant interference level which may enable the link adaptation to adjust the MCS more precisely according to the current link performance. This may improve the throughput of the system.

Accordingly, it is proposed that, as shown in FIG. **2**, a transmitter node may in step **200** determine maximum packet duration for a data packet to be transmitted. This initially determined maximum packet duration may be predefined according to the applied transmission protocol, based on MCS, estimated traffic, mathematical simulations, empirical derivation, etc. As on example, the maximum packet duration may initially be between 0.5 and 0.8 milliseconds.

The type of the data packet may depend on the used transmission protocol, for example. In general, the embodiments are applicable to any transmission technique/protocol. However, in an embodiment, the data packet to be transmitted is a Physical Layer Convergence Procedure (PLCP) Protocol Data Unit (PPDU) of an IEEE 802.11 wireless access network. Thus, the packet duration may be the PPDU duration. The duration may be defined by determining the size/length of the PPDU to be transmitted. An example data packet is shown in FIG. **3**A, wherein the PPDU **300** is depicted. The bidirectional arrow in FIG. **3**A shows the length/size/duration of the PPDU **300**.

The data packet may comprise a plurality of data units. Although the data units may be seen as any sub-parts within the transmitted data packet, in an embodiment each data unit in the data packet is a MAC Protocol Data Unit (MPDU) of an IEEE 802.11 wireless access network.

Although in the following the terms PPDU and MPDU may be used for simplicity, the embodiments may as well be applicable to other types of data packets comprising many data units. FIG. **3**A also shows how the PPDU **300** may comprise multiple MPDUs **301-310**.

The transmitter node may, in an embodiment, be a non-AP STA, such as the STA **102** transmitting data to the STA **106**, for example. In another embodiment, the transmitter node is an access point or access node, such as the AP **100**. In an embodiment, the transmitter node operates according to the wireless local area network of the IEEE 802.11.

In step **202**, the transmitter **102** may cause a transmission of the PPDU comprising the plurality of MPDUs. The data packet may be transmitted to a receiver, such as to the STA **106** of FIG. **1**. The transmission may take place within a transmission period T_{TX}. The transmission period T_{TX} needed for transmitting the packet may depend on the initial maximum packet duration.

In an embodiment, the transmitter **102** may use ready-to-send/clear-to-send (RTS/CTS) signaling, as shown in FIG. **3**B. This may be in order to overcome possible hidden terminal problems and to reduce the likelihood of transmission collisions **110**. Also enhanced distributed channel access (EDCA) parameters may be adjusted to reduce collisions. These parameters may comprise e.g. a contention window (CW) minimum and maximum, an arbitrary inter-frame space (AIFS) and a transmission opportunity (TXOP) limit setting a time period during which the transmitter **102** is allowed to transmit without contention.

The transmitter **102** may detect if no acknowledgement or no block acknowledgement is received from the receiver (responder) **106** for the transmitted data packet **300**. The lack of ACK may be because the reception of the synchronization sequence or the PLOP header of the data PPDU **300** by the STA **106** was not successful, none of the transmitted MPDUs **301-310** of the transmitted PPDU **300** was received correctly by the STA **106**, and/or the reception of the ACK frame by the STA **102** from the receiver **106** has failed. However, if one or more of the MPDUs **301-310** in the PPDU **300** was received correctly by the receiver **106**, the receiver **106** may transmit and the STA **102** may receive the ACK frame in step **204**, such as a block ACK, that indicates which one(s) of the MPDUs **301-310** was/were received correctly by the receiving STA **106** and which one(s) was/were not received (failed reception) by the receiving STA **106**. This is shown in FIG. **3**B in which the receiver STA **106** transmits an ACK or a block ACK frame **320**A, **320**B (commonly referred to as ACK **320**) after each transmitted PPDU **300**A, **300**B (commonly referred to as PPDU **300**).

Let us now assume that at least some consecutive MPDUs (data units) were not received correctly by the receiving STA **106**. That is the received ACK **320** may indicate a failed reception of multiple consecutive data units of the transmitted data packet. This is shown in FIGS. **4**A and **4**B. In both figures, the ACK frame **320** shows that at least some consecutive (adjacent) data units were not received correctly by the receiver **106**. In the example FIG. **4**A, the missed data units are the MPDUs **308-310**, and in the example of FIG. **4**B, the missed data units are the MPDUs **305-310**. The missed data units are marked with blocks having right leaning diagonal lines, whereas the correctly received data units are marked with white blocks. As some MPDUs are not been received correctly by the receiver STA **106**, the transmitter STA **102** may consider that some third devices are not aware that the channel is being reserved. Consequently, these third device(s), such as the STA **104** and/or **108**, may have started transmitting during the on-going communication between the STAs **102** and **106**. This may lead to collided transmissions **110** and inefficiency in the communication.

In step **206**, the transmitter STA **102** may determine a transmission duration T_{FAIL} during which the failed multiple consecutive data units were transmitted. The time interval T_{FAIL} may be comprised within the total transmission period T_{TX} of the data packet **300**. The transmitter **102** may be aware of the transmission time instants for each of the MPDUs **301-310** of the PPDU **300**. By receiving information that, e.g., the reception of MPDUs **308-310** have been failed, the transmitter **102** may then determine, on the basis of the stored transmission times of the MPDUs **301-310**, how long it took to transmit these three failed MPDUs **308-310**. Thus, the transmitter STA **102** may be able to determine the T_{FAIL}.

In step **208**, the STA **102** may then determine whether or not to adjust the maximum packet duration (e.g. the maximum PPDU duration) for upcoming data packet transmissions on the basis of the determined transmission duration T_{FAIL}. Such adjustment of the maximum PPDU size/length/duration may increase the communication efficiency of the wireless access network, as will be described below.

For example, it may be noted that, e.g., shortening of the transmitted PPDUs **300** may reduce the number of failed MPDU receptions during a transmission opportunity (TXOP). The negative effect caused by the increased ACK overhead (due to shortening of the PPDU size) may be smaller than the negative effect otherwise caused by a reduced physical (PHY) layer transmission rate or by the time wasted for the MPDU retransmissions. As one possible further advantage, smaller PPDU size may enable reduced MCS, which may be taken into account by the link adaptation in applying a smaller PHY rate in order to increase transmissions reliability.

Let us take a look on how the STA **102** may decide whether or not to adjust the maximum packet duration by referring to FIGS. **4**A and **4**B. In **4**A, the interval T_{FAIL} corresponds to the time interval for transmitting three consecutive MPDUs **308-310**. In this case T_{FAIL} may be relatively short. In an embodiment, upon detecting that the determined transmission duration T_{FAIL} is lower than a predetermined threshold T_{TH}, the STA **102** may decide to maintain the current value of the maximum packet duration. That is, if the time T_{FAIL} to transmit the failed MPDUs **308-310**, whose reception failed, is small, e.g. within the transmission duration of the ACK **320** (single ACK or block ACK) or the RTS frame, the data transmitter STA **102** may assume that multiple receiver STAs are located closely and they are transmitting ACKs simultaneously during the data PPDU transmission. The STA **102** may determine that these simultaneous ACKs are the reason of the failed reception of the MPDUs **308-310** during the interval T_{FAIL}. The STA **102** may further consider that there are no close-by transmitters. In this case, the data transmitter STA **102** may decide not to react to these errors caused by the ACK/RTS transmissions. As a consequence, the STA **102** may keep the maximum PPDU duration the same. The STA **102** may thus keep on transmitting further PPDUs having the same size, for example.

However, in FIG. **4**B, the determined T_{FAIL} is longer, corresponding to the transmission duration of the MPDUs **305-310**. Let us assume that this duration T_{FAIL} exceeds the predetermined threshold T_{TH}. In this embodiment, upon detecting that the determined transmission duration T_{FAIL} is higher than the predetermined threshold T_{TH}, the transmitter STA **102** may decide to reduce the value of the maximum packet duration. In other words, if the collisions take place over a longer interval, such as over an interval matching other data transmissions, then the missed MPDUs **305-310** may not be due to ACKs being transmitted from other receivers. In this case it is more likely that other transmitter(s) is/are transmitting during the on-going transmission. In such case, the transmitter STA **102** may transmit shorter PPDUs **300** to enable the receiver **106** to transmit ACKs more often and, thus, to allow the NAV information to be updated more often by devices in the proximity. Similarly the synchronization sequence and the PLOP headers are transmitted more frequently by the data transmitter **102**, which also indicates the duration of the transmitted PPDU and set an extended inter-frame space (EIFS) protection around the data transmitter. Together these mechanisms may decrease the collisions in the network.

In an embodiment, the predetermined threshold T_{TH} is set to value which is higher than estimated transmission duration of an acknowledgement frame. The estimated time duration needed for transmitting the ACK **320** may be between 40 and 100 microseconds, for example. Therefore, the T_{TH} may be set to a value between 110 and 150 microseconds, for example. In another embodiment, the predetermined threshold T_{TH} corresponds to the estimated transmission duration of the acknowledgement frame (e.g. the T_{TH} may be set to a value of 100 microseconds). In this embodiment, the STA **102** may detect whether or not the determined maximum packet duration equals to or is lower than the T_{TH}. If the answer is positive, the current value of the maximum duration may be maintained. The exact value of the T_{TH} may be based on mathematical modelling and/or empirical derivation, for example.

In an embodiment, if no MPDUs are missed by the receiver STA **106**, the transmitter STA **102** may decide to increase the value of the maximum packet duration for the future data packet transmissions. This way the system throughput may be increased. However, if it is later recognized that failed MPDU receptions start to occur, the STA **102** may decide to reduce the maximum packet duration, as explained above.

It may be noted that it is the maximum packet duration which is maintained or adjusted. Thus, the transmitter **102** may still transmit any PPDUs **300** which are shorter than the defined maximum packet length. However, the transmitter **102** should not transmit any PPDUs **300** which are longer than the defined maximum duration. By defining the applicable maximum packet duration for transmissions, the transmitter **102** allows the receiver **106** to respond frequently enough, that is, after each PPDU **300** transmission. These responses (e.g. ACKs **320**) may carry also information on how long the channel is reserved by the on-going communication to which the response refers to. Such information may be the NAV update, for example. Thus, third devices, such as the STAs **104**, **108**, may obtain NAV updates more frequently. This may ensure that the third devices do not start any transmissions which may collide with the on-going transmission. As such, the set maximum packet duration may be seen as a parameter defining the maximum duration before response (MDBR) which may be used to control the maximum duration between responses from the receiver **106**.

In an embodiment, the MDBR (i.e. the maximum packet duration) may be included to the EDCA parameters. In an embodiment, the STA **102** may set different maximum packet duration for different access/priority categories, such as for different EDCA access categories. There may be, e.g., a separate MDBR value may be for each AC, and the same MDBR values are applied to all associated STAs capable of handling EDCA parameters. This may improve the flexibility of the system and enhance the communication efficiency in this manner. For example, high priority classes may apply more frequent responses (shorter PPDU size). In this way users having priority data to transmit may more easily be able to transmit the data without collisions.

In an embodiment, the transmitter STA **102** may detect what is the period during which the transmitter is allowed to transmit without contention, e.g. the duration of the TXOP (i.e. TXOPLimit). Thereafter, the transmitter STA **102** may determine the maximum packet duration at least partly on the basis of the period during which the transmitter is allowed to transmit. In this way the value of TXOPLimit may affect to the value of the MDBR (i.e. to the determination of the PPDU size). In an embodiment, if the TXOPLimit is set to "0", i.e. only a single data PPDU is allowed to be transmitted during one TXOP, the STA **102** may decide to keep on transmitting large PPDUs fitting inside the single TXOP. This may contribute to the communication efficiency as maximum amount of data is transmitted within one TXOP.

However, in an embodiment where the TXOPLimit is larger than zero (i.e. the STA **102** may be able to transmit more than one PPDU during one TXOP), the STA **102** may determine the maximum PPDU size so that the transmitted PPDUs **300** within the TXOP have even/uniform duration. This may contribute to the simplicity of the data transmission.

Further, in case the transmitter transmits multiple data packets during one contention-free transmission period (e.g. during one TXOP), the STA **102** may determine the maximum packet duration such that minimum amount of time in the contention-free transmission period is left unused. This may ensure that the TXOP duration is optimally used for data transmission. For example, let us assume that there is a payload for 1.5 ms transmission time according to the current MCS estimate and the TXOPLimit is 2.0 ms. The STA **102** may add the overhead of possible RTS/CTS transmissions (e.g. 120 microseconds) and the overhead of each ACK frame (e.g. 100 microseconds) to the estimated total transmission time. The transmitting device **102** may then compare different configurations and calculate the total transmission time that is consumed for each configuration, as shown in Table 1.

TABLE 1

Example comparison of different options for the number of PPDUs to be used in one TXOP

# of PPDUs in TXOP	Total TXOP duration [ms]	PPDU duration [ms]	Total overhead time [ms]	Total overhead [%]
1	1.5	1.72	0.22	12.79
2	0.75	1.82	0.32	17.58
3	0.5	1.92	0.42	21.88
4	0.375	2.02	0.52	25.74

Let us assume that the STA **102** compares configurations in which the payload is divided into 1, 2, 3 or 4 equal sized PPDUs, as shown in Table 1. As a result of the comparison, the STA **102** may decide to transmit the payload in one, in two or in three 3 PPDUs, as the option with four PPDUs exceeds the TXOP limit. The STA **102** may for example try the option with only one PPDU, and if collisions occur (some MPDUs are not correctly received by the STA **106**), the STA **102** may decide to shorten the PPDU duration and transmit the payload in two or three PPDUs.

In an embodiment, in case the durations of the transmitted PPDUs are not constant, the STA **102** may set maximum data packet duration to a value between 0.5 and 0.8 milliseconds. This may allow enough flexibility for the PPDU sizes, yet keeping the frequency of ACKs **320** from the receiver **106** high enough in order to allow third devices to detect the NAV updates in the ACKs **320**.

In an embodiment, as shown also in FIG. **4**B, the STA **102** may detect, on the basis of the received ACK frame **320**, that a set of consecutive data units transmitted data packet have been received correctly. These correctly received MPDUs, marked with white blocks in FIG. **4**B, may be present in the beginning of the transmitted PPDU **300**. In FIG. **4**B, four data units (MPDUs) **301**-**304** have been received correctly. The STA **102** may then determine a second transmission duration $T_{SUCCESS}$ during which the correctly received set of consecutive data units **301**-**304** were transmitted.

Thereafter, the STA **102** may set the maximum packet duration at least partly on the basis of the determined second transmission duration $T_{SUCCESS}$. For example, if it has been detected that four MPDUs **301**-**304** have been correctly received but after that a collision has occurred, the STA **102** may consider that causing the ACK response to be transmitted before the fifth MPDU **305** may allow the other devices to detect the on-going data communication. Thus, the STA **102** may decide to shorten the PPDU duration and set the maximum PPDU duration to a value which corresponds to the transmission time of four MPDUs, i.e. to $T_{SUCCESS}$. To be on the safe side, the STA **102** may set the PPDU duration to a value which is slightly less than the $T_{SUCCESS}$, in order to make sure that other devices detect the ACK carrying the NAV update early enough so that they do not cause any data transmission. This may help avoiding or at least reducing the number of collisions. The target may be that the STA **102** detects an optimal periodicity for the responses from the receiver **106** and transmits, at maximum, PPDUs which make the receiver to reply according to this optimal periodicity.

Some of the other devices in the communication system may be devices capable of applying a sleep mode for power saving, such as the STA **104**. As shown in FIG. **6**A, after the STA **104** wakes up, the STA **104** may decide to start transmitting in the medium if the STA **104** does not receive any information that there is an on-going communication in the channel already. As said earlier, although the NAV information may be transmitted in the PPDU **300**, the information may not be easily received by all devices. The ACK or block ACK frame **320** may be more easily detectable by other devices. This is because the ACK **320** may be transmitted in lower throughput leading to more robust transmission. However, in the example of FIG. **6**A, the PPDU size applied by the STA **102** is large and the STA **104** waking up from the doze mode may not detect any ACKs **320**. As a result, the power saving STA **104** may start transmission (e.g. RTS request being sent) at point **600**. This RTS transmission may collide with the on-going data transmission and a portion of the PPDU **300** is not received correctly by the STA **106**.

In order to avoid the collision of FIG. **6**A, there is proposed also a mechanism where the AP **100** or another device may coordinate the interval between responses (MDBR) and set a minimum listening time for the power saving STAs **104** after waking from the doze state before starting to obtain a TXOP. Accordingly, in an embodiment, the transmitter may transmit an indication of the maximum packet duration (i.e. an indication of the MDBR) to a group of devices capable of applying a sleep mode for power saving, such as to the STA **104**. This is shown in FIG. **5**. Although FIG. **5** depicts that the AP **100** transmits the indication in order to improve the transmission reliability and communication efficiency, in another embodiment a non-AP STA, such as the STA **102**, may transmit the indication of the MDBR to the group of devices.

In another embodiment, the indication from the AP **100** or from non-AP STA **102** is of a broadcast type and thus detectable by each and every device in the coverage area of the broadcast.

However, let us, for the sake of simplicity, assume that the indication goes to the group of devices capable of applying the sleep mode in step **602**, as shown in FIG. **6**B. These devices, including the STA **104**, may then apply the indicated maximum packet duration (i.e. the MDBR) as a minimum waiting duration **602** before transmitting any data after wake-up from the sleep mode in order to ensure that at least one ACK frame **320** is received. As a result, the STA **104** detects and decodes the ACK **320** from the receiver STA **106** in step **603**. In this manner the STA **104** obtains knowledge that there is an on-going communication in the channel and may restrain from transmissions. This may avoid collisions or at least decrease the number of collisions in the wireless access system. Consequently, the STA **104** may, after waking up, start to obtain a TXOP only after the STA **104** has waited for the MDBR duration during which it receives the ACK frame **320**, if any relevant on-going communication is present.

Looking from the point of view of the power saving STA **104**, the STA **104** may acquire the indication of the maximum packet duration in step **700** of FIG. **7**. In step **702**, the STA **104** wakes up from the sleep mode. In step **704**, unless otherwise indicated earlier, the STA **104** may wait until the expiry of the indicated maximum packet duration before transmitting any data. Owing to the waiting period, the STA **104** may in step **706** receive the ACK frame related to an on-going transmission during the waiting period, wherein the ACK frame carries the information on how long the medium is reserved due to the on-going communication to which the ACK frame corresponds to. In this way other devices may trust that by transmitting PPDUs **300** with the defined maximum PPDU duration, there will most likely be no distortions in the channel due to transmission from the STAs **104** that are waking up. However, in case the STA **104** receives a frame (preamble) before the end of the MDBR period, the STA **104** may proceed directly to transmission without waiting till the end of the MDBR period.

In one embodiment, the multicast/broadcast of the maximum packet duration is targeted also to other STAs **108**, not only to power saving STAs **104**. The STA **108** in the role of a transmitter may apply the information in the same manner as the transmitter **102**, that is, by allowing the recipient to respond at minimum between the MDBR duration. This may take place by the STA **108** coordinating the number of octets in transmission so as to fulfil the indicated MDBR requirements. This may increase the reliability and the communication efficiency in the system.

In case the multicast/broadcast of the maximum packet duration is made by an AP, such as the AP **100**, the AP **100** may include the indication of the maximum packet duration in at least one of the following: an association response, a beacon and a probe response. This may be efficient from the system efficiency point of view so that no extra signaling is needed to inform the maximum packet duration.

In an embodiment, the AP **100**, or a non-AP STA, may transmit (e.g. multicast) the indication of the maximum packet duration (MDBR) to a predetermined group of devices applying the same access window for transmission, such as to a group of devices operating within the same Reduced Access Window (RAW). The RAW may be used to allow different devices to access the channel at different times. A target of the RAW may be group devices that are allowed to transmit to the AP **100** at certain times, for example. It may be beneficial that the MDBR is taken into use by a certain group only. This may increase the flexibility of the system.

In an embodiment, the indicated MDBR may be utilized so that the terminals belonging to the predetermined group may allow a receiver of communication to transmit (e.g. to reply with ACK) at maximum after the MDBR delay.

In one embodiment, the indicated MDBR may be utilized so that the power saving STAs **104** that wake from Doze and belong to the predetermined group may transmit only after the MDBR delay, unless an they are allowed to do so earlier by receiving a preamble, for example. Power saving STAs that do not belong to predetermined group may not be allowed to transmit.

In yet one embodiment, the indicated MDBR may be utilized so that the terminals that do not belong to the predetermined group may transmit after the MDBR duration. In this case, the MDBR may be set to a value larger than TXOPLimit in order to allow other STAs to take the unused channel into usage. This may increase the efficiency of the system.

In an embodiment, the AP **100** or a non-AP STA **102** may transmit the MDBR information to an individual address. In case the value is transmitted by a non-AP STA to an AP, the indication of the MDBR is considered by the AP only as a recommendation for the AP. The AP may itself decide whether or not to take the indicated MDBR value into use. For example, if the AP knows that shorter maximum packet duration is used by some other STA, the AP may decide not to follow the suggested MDBR. Moreover, the AP may decide to indicate the shorter MDBR to the STA which suggested the longer MDBR.

In one embodiment, the MDBR (i.e. the maximum packet duration) may be applied by the STA **104** only when unexpected conditions take place. For example, in an embodiment, the STA **104**, after waking up, may apply the indicated maximum packet duration as the waiting period only for transmissions taking place at some other time instant than at indicated in a transmission schedule. Thus, normal real-time transmission according to the schedule may be done without additional delays.

An embodiment, as shown in FIG. **8**, provides an apparatus **800** comprising a control circuitry (CTRL) **802**, such as at least one processor, and at least one memory **804** including a computer program code (PROG), wherein the at least one memory **804** and the computer program code (PROG), are configured, with the at least one processor **802**, to cause the apparatus **800** to carry out any one of the described processes. The memory **804** may be implemented using any suitable data storage technology, such as semiconductor based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory.

In an embodiment, the apparatus **800** may be or be comprised in a terminal device of a wireless access communication system, e.g. a user equipment (e.g. the STA **102**), a user terminal (UT), a computer (PC), a laptop, a tabloid computer, a cellular phone, a mobile phone, a communicator, a smart phone, a palm computer, or any other communication apparatus. Further, the apparatus **800** may be or comprise a module (to be attached to a device, such as to the STA **102**) providing connectivity, such as a plug-in unit, an "USB dongle", or any other kind of unit. The unit may be installed either inside the device or attached to the device with a connector or even wirelessly. In an embodiment, the apparatus **800** may be or be comprised in a wireless device operating under the IEEE 802.11, for example. In another embodiment, the apparatus **800** may be or be comprised in a network node, such as in an access point or an access node operating under the IEEE 802.11.

The apparatus **800** may further comprise communication interface (TRX) **806** comprising hardware and/or software for realizing communication connectivity according to one or more communication protocols. The TRX **806** may provide the apparatus with communication capabilities to access the wireless radio access network, for example.

The apparatus **800** may also comprise a user interface **808** comprising, for example, at least one keypad, a microphone, a touch display, a display, a speaker, etc. The user interface **808** may be used to control the apparatus **800** by the user.

The control circuitry **802** may comprise a transmission control circuitry **810** for setting the initial PPDU size and for causing the transmission of the PPDU comprising the plurality of MPDUs, for example. An acknowledgment frame analysis circuitry **812** may be for analysing the received ACK frames in order to know which one(s) of the MDPUs of the

PPDU were not correctly received by the receiver, for example. A packet duration control circuitry **814** may set the maximum packet duration allowed, according to any of the embodiments.

In case the apparatus **800** is or is comprised in a power saving STA, such as the STA **104**, the controller **802** may additionally comprise a sleep mode control circuitry **816** for controlling the dozing and awake periods as well as for controlling the waiting duration before accessing the channel.

As used in this application, the term 'circuitry' refers to all of the following: (a) hardware-only circuit implementations, such as implementations in only analog and/or digital circuitry, and (b) combinations of circuits and soft-ware (and/or firmware), such as (as applicable): (i) a combination of processor(s) or (ii) portions of processor(s)/software including digital signal processor(s), software, and memory(ies) that work together to cause an apparatus to perform various functions, and (c) circuits, such as a microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present. This definition of 'circuitry' applies to all uses of this term in this application. As a further example, as used in this application, the term 'circuitry' would also cover an implementation of merely a processor (or multiple processors) or a portion of a processor and its (or their) accompanying software and/or firmware. The term 'circuitry' would also cover, for example and if applicable to the particular element, a baseband integrated circuit or applications processor integrated circuit for a mobile phone or a similar integrated circuit in a server, a cellular network device, or another network device.

The techniques and methods described herein may be implemented by various means. For example, these techniques may be implemented in hardware (one or more devices), firmware (one or more devices), software (one or more modules), or combinations thereof. For a hardware implementation, the apparatus(es) of embodiments may be implemented within one or more application-specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), processors, controllers, micro-controllers, microprocessors, other electronic units designed to perform the functions described herein, or a combination thereof. For firmware or software, the implementation can be carried out through modules of at least one chip set (e.g. procedures, functions, and so on) that perform the functions described herein. The software codes may be stored in a memory unit and executed by processors. The memory unit may be implemented within the processor or externally to the processor. In the latter case, it can be communicatively coupled to the processor via various means, as is known in the art. Additionally, the components of the systems described herein may be rearranged and/or complemented by additional components in order to facilitate the achievements of the various aspects, etc., described with regard thereto, and they are not limited to the precise configurations set forth in the given figures, as will be appreciated by one skilled in the art.

Embodiments as described may also be carried out in the form of a computer process defined by a computer program. The computer program may be in source code form, object code form, or in some intermediate form, and it may be stored in some sort of carrier, which may be any entity or device capable of carrying the program. For example, the computer program may be stored on a computer program distribution medium readable by a computer or a processor. The computer program medium may be, for example but not limited to, a record medium, computer memory, read-only memory, electrical carrier signal, telecommunications signal, and software distribution package, for example. Coding of software for carrying out the embodiments as shown and described is well within the scope of a person of ordinary skill in the art.

Even though the invention has been described above with reference to an example according to the accompanying drawings, it is clear that the invention is not restricted thereto but can be modified in several ways within the scope of the appended claims. Therefore, all words and expressions should be interpreted broadly and they are intended to illustrate, not to restrict, the embodiment. It will be obvious to a person skilled in the art that, as technology advances, the inventive concept can be implemented in various ways. Further, it is clear to a person skilled in the art that the described embodiments may, but are not required to, be combined with other embodiments in various ways.

The invention claimed is:

1. A method, comprising:

determining, by a transmitter node, maximum packet duration for a data packet to be transmitted, wherein the data packet comprises a plurality of data units;

causing a transmission of the data packet;

causing a reception of an acknowledgement frame indicating a failed reception of multiple consecutive data units of the transmitted data packet;

determining a transmission duration during which the failed multiple consecutive data units were transmitted; and

determining whether or not to adjust the maximum packet duration for upcoming data packet transmissions on the basis of the determined transmission duration.

2. The method of claim **1**, further comprising:

upon detecting that the determined transmission duration is lower than a predetermined threshold, maintaining the current value of the maximum packet duration; and

upon detecting that the determined transmission duration is higher than the predetermined threshold, reducing the value of the maximum packet duration.

3. The method of claim **2**, wherein the predetermined threshold set to a value which is higher than estimated transmission duration of the acknowledgement frame.

4. The method of claim **1**, further comprising:

detecting, on the basis of the received acknowledgment frame, that a set of consecutive data units in the transmitted data packet have been received correctly;

determining a second transmission duration during which the correctly received set of consecutive data units were transmitted; and

setting the maximum packet duration at least partly on the basis of the determined second transmission duration.

5. The method of claim **1**, wherein each acknowledgement frame comprises information on how long the medium is reserved due to the on-going communication to which the acknowledgment frame corresponds to, the method further comprising:

causing an indication of the maximum packet duration to a group of devices capable of applying a sleep mode for power saving, wherein the group of devices applies the indicated maximum packet duration as minimum waiting duration before transmitting any data after wake-up from the sleep mode in order to ensure that at least one acknowledgement frame is received.

6. The method of claim **5**, further comprising:

including the indication of the maximum packet duration in at least one of the following: an association response, a beacon and a probe response.

7. The method of claim 1, further comprising: causing a transmission of an indication of the maximum packet duration only to a predetermined group of devices applying the same access window for accessing channel.

8. The method of claim 1, wherein the data packet is a Physical Layer Convergence Procedure Protocol Data Unit, PPDU, and the data unit comprised in the data packet is a MAC Protocol Data Unit, MPDU, of an IEEE 802.11 wireless access network.

9. The method of claim 1, wherein the transmitter node is a user device or an access point of an IEEE 802.11 wireless access network.

10. An apparatus, comprising:

at least one processor and at least one memory including a computer program code, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus at least to:

determine maximum packet duration for a data packet to be transmitted, wherein the data packet comprises a plurality of data units;

cause a transmission of the data packet;

cause a reception of an acknowledgement frame indicating a failed reception of multiple consecutive data units of the transmitted data packet;

determine a transmission duration during which the failed multiple consecutive data units were transmitted; and

determine whether or not to adjust the maximum packet duration for upcoming data packet transmissions on the basis of the determined transmission duration.

11. The apparatus of claim 10, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus further to:

upon detecting that the determined transmission duration is lower than a predetermined threshold, maintain the current value of the maximum packet duration; and

upon detecting that the determined transmission duration is higher than the predetermined threshold, reduce the value of the maximum packet duration.

12. The apparatus of claim 11, wherein the predetermined threshold set to a value which is higher than estimated transmission duration of the acknowledgement frame.

13. The apparatus of claim 10, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus further to:

detect, on the basis of the received acknowledgment frame, that a set of consecutive data units in the transmitted data packet have been received correctly;

determine a second transmission duration during which the correctly received set of consecutive data units were transmitted; and

set the maximum packet duration at least partly on the basis of the determined second transmission duration.

14. The apparatus of claim 10, wherein each acknowledgement frame comprises information on how long the medium is reserved due to the on-going communication to which the acknowledgment frame corresponds to, and wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus further to:

cause an indication of the maximum packet duration to a group of devices capable of applying a sleep mode for power saving, wherein the group of devices applies the indicated maximum packet duration as minimum waiting duration before transmitting any data after wake-up from the sleep mode in order to ensure that at least one acknowledgement frame is received.

15. The apparatus of claim 14, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus further to:

include the indication of the maximum packet duration in at least one of the following: an association response, a beacon and a probe response.

16. The apparatus of claim 10, wherein the at least one memory and the computer program code are configured, with the at least one processor, to cause the apparatus further to:

cause a transmission of an indication of the maximum packet duration only to a predetermined group of devices applying the same access window for accessing channel.

17. The apparatus of claim 10, wherein the data packet is a Physical Layer Convergence Procedure Protocol Data Unit, PPDU, and the data unit comprised in the data packet is a MAC Protocol Data Unit, MPDU, of an IEEE 802.11 wireless access network.

18. The apparatus of claim 10, wherein the apparatus is a user device or an access point of an IEEE 802.11 wireless access network.

19. A non-transitory computer readable medium embodying at least one computer program code, the at least one computer program code executable by at least one processor to perform operations comprising:

determining maximum packet duration for a data packet to be transmitted, wherein the data packet comprises a plurality of data units;

causing a transmission of the data packet;

causing a reception of an acknowledgement frame indicating a failed reception of multiple consecutive data units of the transmitted data packet;

determining a transmission duration during which the failed multiple consecutive data units were transmitted; and

determining whether or not to adjust the maximum packet duration for upcoming data packet transmissions on the basis of the determined transmission duration.

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